The Analysis of Students' Spatial Ability at Senior High School in Banda Aceh

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Abstract

Spatial ability is one of the abilities required during mathematics teaching learning process in schools based on the curriculum's mandate. To deal with, teachers should be able to choose a learning approach that is able to develop the capability. Spatial ability can be measured through the ability to rotate, alter, move, perceive an object and also determine the relationship between one part with other parts. Furthermore, this skill can be noticed of the ability to identify the basic logic of a pattern and determine the solution which is called as the abstract reasoning. This study aims to describe the spatial ability of the second grade of high school. The research involved 30 students of grade XI IPA 3 at such as one of senior high school in Banda Aceh. The instruments used in this research were spatial ability test and semi structured interview. The results of this study show that most of the students were able to determine the rotation of an object and abstract reasoning on the archetype. However, there is a minor percentage of students who were able to visualize, perceive, and determine the relationship between a part and other parts of a three-dimensional object.

Keywords: Analysis, spatial ability, mathematic, geometry.

Introduction

The spatial reasoning ability is the ability which involves a person's cognitive processes in the manipulating and transforming the form of a 2D or 3D object both in its position change, perception, being able to imagine how the object looks when viewed from various positions, and imagining an abstract object. These capabilities include the spatial visualization aspects and spatial orientation, such as the reading a picture skill and representing a two-dimensional picture of a three-dimensional object based on different angles. (Black, 2015) explained that spatial ability is the ability to present, transform, construct, and recall symbolic information in unlanguaged form. Furthermore, Lohman (1996) defined that spatial ability is the ability to generate, maintain, recall, and transform visual images which are well structured. Meanwhile, according to National Academy of Science (2006), spatial thinking is a collection of cognitive skills including a combination of three elements which are spatial concepts, presentation tools, and reasoning process. Consequently, it can be concluded that spatial ability is the mental intelligence in understanding objects that are abstract in perceiving, transforming the structured objects, changing, maintaining and communicating geometry.

Spatial thinking is needed in numerous knowledge areas such as science, technology, engineering, and mathematics (STEM) (Hegarty and Waller), as well as

in solving daily problems. For instance, spatial abilities are often used to set up a pole, pin a picture frame on the wall, predict unvisitable dice and make nets of geometry. In the professional world, spatial skills are extensively used for those who have expertise such as architects, cartoon designer, three-dimensional animated films director and so on (Subroto, 2016). Moreover, spatial ability is used to measure the level of one's intelligence. According to Spearmen (Newton & Bristoll, 2010), a person having good intelligence must be good at vocabulary, math and spatial skills. He developed test to measure intelligence levels which were specified into mechanical, verbal, numerical, and spatial. This intelligence test capability is often used for the school admission selection test, the state college entrance test and even the selection of officer requirement. Strong and Roger (Syahputra, 2016) stated that in the industrial technology, spatial ability is very useful in applications such as simulation, multi-media and modeling. Meanwhile, Branoff (2013) stated that besides the ability to recognize symbols and the standard of understanding, student's spatial visualization abilities in geometry also affect student's capability to interpret engineering drawings.

According to NCTM (2000) there are five standard contents in school mathematics standards, namely numbers and operations, problem solving, geometry, measurement, probability, and data analysis. In Indonesia, geometry including in the Mathematics curriculum has been studied since elementary school up to college level. In the revision of Indonesian national curriculum, geometry has been learnt at the elementary to upper secondary level where it requires spatial ability. National Academy of Science (2016) revealed that every student should try to develop the spatial capabilities and the sense in order to understand the relationships and properties in geometry to solve math problems as well as daily life problems. Considering the importance of this spatial ability, it is important to note that teachers develop learning strategies that can promote the students' spatial skills. Therefore, the information about how students' spatial abilities are needed to recommend the teachers developing the instructional ideas.

Spatial ability can be measured by understanding the ability to perceive objects which are observed either horizontally or vertically, showing the rules of change or transfer of the compilers of a three dimensional to two-dimensional or vice versa, rotating two-dimensional and three-dimensional objects precisely and accurately, understanding the composition of a objects and their parts and their relationships with each other, and observing an object from various circumstances either front, side or back. Maier (1998) divided spatial intelligence into five elements of spatial ability: (a) Spatial Perception, (b) Visualization, (c) Mental Rotation, (d) Spatial Relations, and (e) Spatial Orientation. Furthermore, Spearman (Burton and Newton, 2010) developed a test to measure intelligence levels with one of the abilities achieved which are spatial abilities of abstract reasoning. Abstract reasoning tests are usually given in the diagrams form, symbols and fields that involve the identifying on basic pattern then it determines the solution in visual form. In this study, to measure the spatial ability, the indicator based on the combination of Maeir and Spearman which include mentally rotation, visualization, spatial relation, perception, and abstract reasoning is conducted. One of the education level that studies geometry which needs the spatial skills is senior high school. Consequently, it is necessary to find out the students' spatial ability as the input for Mathematics teacher(s).

Based on the previous description of the problem, this study formulates that is "How is the spatial ability of grade XI students at senior high school in Banda Aceh?"

Research Method

The students involved in this research are 30 students of class XI SMA Laboratory of Syiah Kuala University. The instrument of this research is spatial ability test and semi structured interview. The spatial ability test provided consists of 45 items in the form of image matching and multiple choice. Spatial ability test questions are derived from spatial ability tests developed by Prabowo, A (2011), Newton & Bristoll (2010), Disha Publication (2011), and Free Management Ebooks (2015). The test used is refers to the opinion of Maeir (1998) and Spearman (1920). The test indicators are (1) mental rotation, (2) visualization, (3) spatial relations, (4) perception. The following details of the distribution of questions based on indicators:

Table 1. Indicators of Spatial Ability

No	Indicators	Number of The Question	Type of the question
1	Mental Rotation	25 Question	Shape matching
2	Visualization	3 Question	Multiple choice
3	Spatial Relations	3 Question	Multiple choice
4	Perception	4 Question	Multiple choice
5	Abstract Reasoning	10 Question	Multiple choice

The students are considered capable or fulfill each indicator if able to answer correctly more than half of number the problems given in each indicator spatial ability.

Results and Discussion

The abilities for the aspects of Mental Rotation and abstract reasoning have been largely covered by students. As for the ability of Visualization, Spatial Relations, and Perception, only few students have covered it. The data of spatial ability test results are presented in the following table.

Table 2. The Spatial ability test results

No	Indicators	Number of the students	Percentage
1	Mental Rotation	27	90%
2	Visualization	12	40%
3	Spatial Relations	10	33,3%
4	Perception	6	20%
5	Abstract Reasoning	17	57%

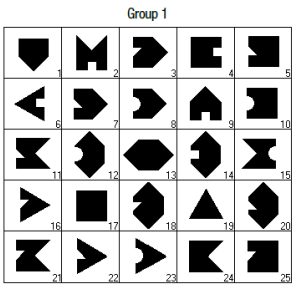
Based on Table 2, the students' spatial ability based on the spatial ability indicator can be explained as follows.

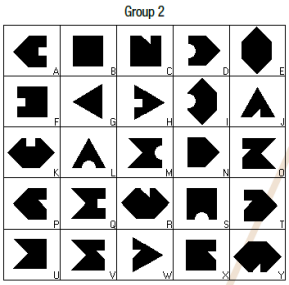
Based on the results of research conducted, of the five indicators of spatial ability, mental rotation ability or the ability of students to determine the results of two-dimensional object rotation is a capability almost dominated by all students of grade XI at SMA Unsyiah Laboratorium Unsyiah. There are 27 students covered mental rotation, while three more students have not covered this ability yet. The form of questions given for the mental rotation aspect.

Mental Rotation

The form of questions given to measure the mental rotation is as follows.

Which shape in Group 2 corresponds to the shape in Group 1?





Answer

1 is	10 is	19 is . . . .
2 is	11 is	20 is . . . .
3 is	12 is	21 is . . . .
4 is	13 is	22 is . . . .
5 is	14 is	23 is . . . .
6 is	15 is	24 is . . . .
7 is	16 is	25 is . . . .
8 is	17 is	
9 is	18 is	

In this problem, students were asked to define the pair of fields contained in group 2 which are the result of rotation by a certain angle of fields in group 1. If students were able to determine more than 12 pairs of appropriate fields, then students categorized have covered the mental ability of rotation.

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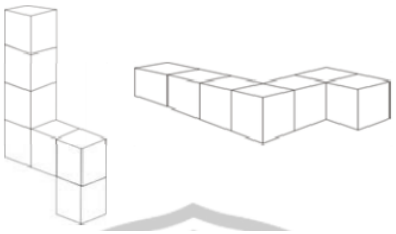
Based on the results of spatial ability tests that have been done, it was found that mental rotation ability is the ability of being overwhelmed by all students. It was obtained that 27 of 30 students have been able to cover this ability, while three more students have not. Two of three students stated that they could not correctly determine the rotation of the field because it was less precise when matching the fields of the two groups, while one student again stated that the cause is a misunderstanding to the instructions matter. She had two assumptions about the first question. First, she assumed that the purpose of the direction was to determine the pairs of fields found in group 2 which are the result of rotation by a certain angle of fields in group 1. The second assumption was the direction of the question asked to determine the exact pair of fields in both groups which were pieces of a particular field.

Based on the highest ranking results for the mental aspects of rotation, male students were more dominant than female students. Battista (1990), Cherney (2008), Delgado and Prieto (2004), and Linn and Petersen (1985) also found the same thing that men are superior to women in mental rotation ability. In this study, mental rotation ability is only tested to determine the rotation of two-dimensional objects. Meanwhile, according to Maeir (1998), the mental rotation ability should contain the ability to rotate two-dimensional and three-dimensional objects.

The mental rotation ability is very useful for students in learning geometry. Students who were good of mental rotation skills tend to be better in geometric achievement (Battista, 1990; Delgado & Prieto, 2004). The example of mental rotation ability in the triangle is determined the base and height of the triangle in different positions.

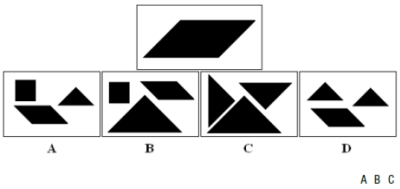
While in the three-dimensional, this mental rotation ability helps someone to see the field when rotated in different positions. For example, looking at the arrangement of some cubes as shown in the picture below.



Visualization Spatial

The form of questions given to measure the visualization spatial is as follows.

Directions: The question in this program consists of a numbered picture showing a solid shape and a set of four lettered cut up pattern pieces. Choose the combination of cut-up pieces that, when put together, will make up the shape shown. Pieces may need to be turned around or turned over to make them fit.



In this problem, students were asked to determine the exact pieces of the field which was given. The numbers of questions to measure the visualization ability consist of 3 questions. If students were able to answer more than one question, then students were considered to cover this aspect.

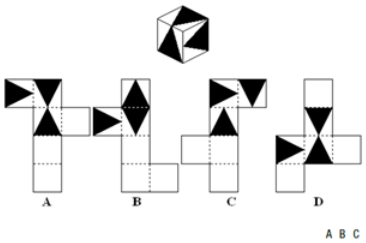
Based on the results of spatial ability tests, most students have not covered the visualization ability. There were 12 students who had covered this ability, while 18 students had not been able to cover it. Three of 18 students were unable to answer the three questions given, while 15 students just could answer one question. Students were difficult to determine the right choice because they were not able to imagine how the relation of the pieces of the field to form the plane in their minds.

The low students' ability of spatial visualization can be influential in understanding the concept of geometry because this ability is closely related to space, chart, shape, and space (Nurhayana, Dantes & Candiasa, 2013). Wackbaker (2014) argued that the visualization ability is more influence on student achievement in algebra. Battista (1981) suggested that visualization abilities support the ability in algebraic structures. Thus, the visualization ability is very influential in learning mathematics both geometry and algebra.

Relation Spatial

The form of questions given to measure the Relation Spatial is as follows.

Which of the patterns when folded will make the cube shown?



In this problem, students were asked to determine the appropriate nets of the given cube. The numbers of questions to measure the relation spatial ability consist of 3 questions. If students were able to answer more than one question, then students were considered to cover this aspect. The relation spatial ability used in this problem was to know the triangle from the side of the cube when it turned into a cube net.

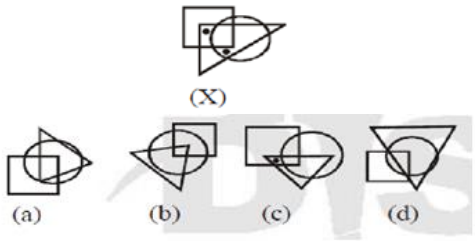
Based on the results of spatial ability tests, only a minority of students have covered the relation spatial ability well. Suparya (2007) also found that the relation spatial ability was still relatively low in the spatial ability. There were 10 students who had mastered this ability, while 20 students had not mastered it yet. Six of 20 students were unable to answer the three questions given, while 14 students just could answer one question. Students were not able to determine the relationship of cube sides contained a triangle image when it turned to the nets. It showed that the relation spatial ability was inseparable from the visualization ability.

The relation ability is the ability to understand the spatial nature of an object or part of the object and its relationship between one part with another. The determination of relationships is not only on the spatial, but also in the solution of mathematical problems which is called connections.

Perception

The form of questions given to measure the perception is as follows.

Direction: from amongst the figures marked (a), (b), (c), and (d), select the figure which satisfies the same conditions of placement of the dot as in fig (X)



In this problem, the student was asked to choose a figure that qualifies the placement of points as shown (X). The numbers of questions to measure perception ability consist of 4 questions. If students were able to answer more than one question, then students categorized have covered the perception ability. The ability required of the problem was how to select a figure that matched the point position in the intersecting plane.

Based on the results of spatial ability tests, only a minority of students have covered the perception ability well. Suparyan (2007) also found that the perception spatial ability was still relatively low in the spatial ability. The number of students who had covered this ability was six students, while 24 students had not covered it yet. Six of 24 students were unable to answer the nine questions given, while 18 students just could answer one question correctly. The student's difficulty was determined by the position of the point which is the incision of several fields. In addition, due to lack of

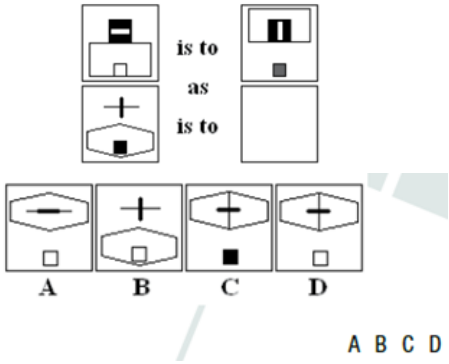
caution in seeing the position of the point, and do not understand with the direction of problem.

The ability of spatial relation and perception are the spatial ability that the lowest compared to other abilities. This is shown by just less than half were not be able to cover these both abilities. Both of these abilities play a role in understanding the concept of geometry such as determining the position of points and lines in the solid geometry of space and relations.

Abstract Reasoning

The form of questions given to measure the Abstract Reasoning is as follows.

Which figure completes the statement?



In this problem, the student was asked to select a suitable image to fit the condition like the image pair on it. The numbers of questions to measure abstract reasoning ability consist of 9 questions. If students were able to answer more than four questions, then students categorized have covered the abstract reasoning ability.

Based on the results of spatial ability tests, the majority of students have been covered abstract reasoning ability. There were 17 students having the capability to answer more than half of the questions enquired correctly, while 13 students had not mastered it yet. The most common mistake students make on this indicator was determination code of the figure that given based on the previous information. This is an example of how to determine the code.

Find which code matches the shape or pattern given at the end of question.

Abstract reasoning ability is part of the spatial ability test form developed by Spearmen (1920). The abstract reasoning test uses diagrams, symbols or fields in place of words or numbers. This test is commonly used to measure the level of intelligence. Thus, students who covered abstract reasoning ability have a good level of intelligence as well.

Conclusions

Based on the results of spatial ability tests that have been done can be concluded that the ability of mental rotation and abstract reasoning is able to cover well with more than half the number of students. While the ability visualization, relation, and perception have been able to cover well less than half the number of students. This shows that the overall spatial ability of students is still relatively low. This can be a

reference for teachers so that choose the learning approach that can improve students' spatial ability.

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